A systematic variation is noted in the absolute values of ultra-violet radiation from year to year. From a maximum in 1915–16 the value decreased to a minimum in about 1922, and again reached a maximum in 1926. The amplitude of the monthly variations (difference between the maximum and the minimum values, expressed as a percentage of the mean value for the period 1915–1927) varied from 34 per cent in April to 52.3 per cent in July.

Since the sun spot maximum occurred in 1917, and presumably also in 1928, with the minimum in 1923, it appears to the author as has been claimed by him since 1917, that the emitted solar radiation is the strongest at the beginning of solar activity, instead of at its maximum, and, analogously, the same is true for the minimum.

Meteorologists are greatly indebted to Professor Dorno for the excellent summary of his observational work on solar radiation at Davos. Unfortunately it is not possible in a brief review to bring out all the important information it contains.

My thanks are due to Mr. W. W. Reed for assistance in interpreting some passages in the German text.

SUMMARY OF THE PRESENT STATE OF OUR KNOWLEDGE OF THE DISTRIBUTION OF OZONE IN THE UPPER ATMOSPHERE

546.214

By G. M. B. DOBSON

[Boars Hill, Oxford, England, February 18, 1929]

By the very kind cooperation of several meteorologists we have been able to make a study of the distribution of ozone under different meteorological conditions by observations at six stations in northwest Europe during four months in 1926 and eight months in 1927. A full account of this investigation is published in the Proceedings, Royal Society of London,[1] together with the results of a year's observations at Montezuma, Chile, and the first values from a new series of observations begun at California,

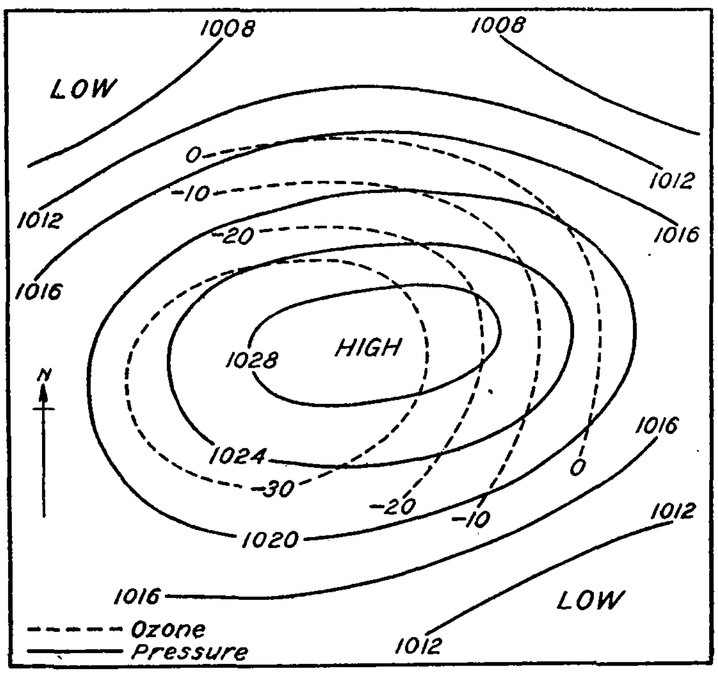

FIGURE 1.—Variation of ozone in connection with an anticyclone

Egypt, south India, and New Zealand. The most important results of these observations, together with those of other workers, are summarized below.

I. The variations of the amount of ozone with different meteorological conditions, with different times of year and with different latitudes is best seen by means of Figures 1, 2,[2] and 3.[3] Since the number of observations is small the diagrams must not be trusted for small details. (The average amount of ozone is equivalent to a layer of the pure gas some 3 mm. thick at 0° C. and 760 mm. Hg. The unit used in the diagrams is 0.01 mm. of the pure gas.)

II. The amount of ozone is more closely related to the conditions in the upper air than to those at the surface.

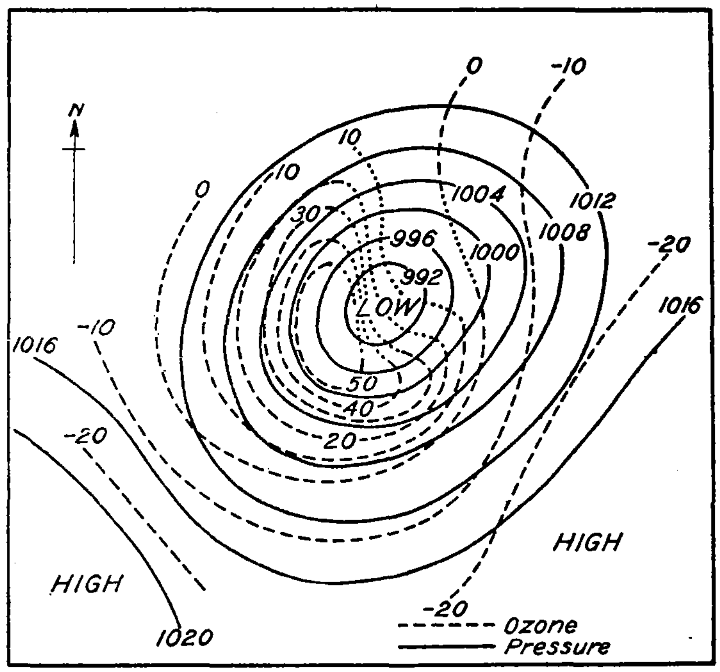

FIGURE 2.—Variation of ozone in connection with a cyclone

The connection with the conditions at 10 to 15 kms. is very close. There are not enough free-air observations to

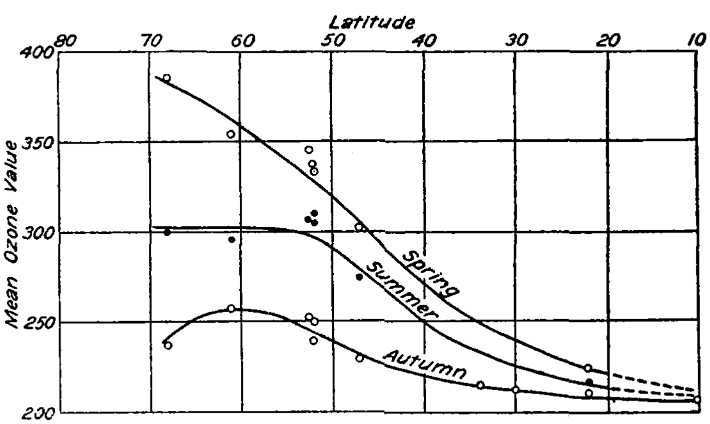

FIGURE 3.—Variation of ozone with season and latitude

show whether this connection is closer or less close at still greater heights. The amount of ozone is correlated:

[1] Dobson, Harrison & Lawrence. Roy. Soc. Proc. A, vol. 122, p. 456 (1929).
[2] Reproduced by permission of the Council of the Royal Society from the Proceedings.
[3] Reproduced by permission of Geh. Prof. Hergesell from Beit. Phys. d. f. Atmos.

a. Positively to the pressure at the base of the stratosphere.
b. Negatively with the height of the base of the stratosphere.
c. Negatively with the pressure at 10 kms.
d. Negatively with the temperature of the troposphere.
e. Negatively with the density of the air at 15 kms. (as shown by Dr. Duckert).
f. Positively (but less closely than the above) with the temperature of the stratosphere.

The correlation coefficient in the first five cases is about 0.7 to 0.8, and it is difficult to say in which case the connection is the closest.

g. The amount of ozone is also closely related to the the origin of the air currents in the upper part of the troposphere. Polar currents are associated with much ozone and equatorial currents with little ozone.

III. The average height of the ozone layer in temperate regions is about 45 to 50 kms. This is shown by the observations of M. M. Cabannes and Dufay, and of M. M. Lambert, Déjardin, and Chalonge in France, and by those of Professor McLennan and his associates in Canada. These observations were made shortly before sunset or after sunrise. Very numerous observations by Doctor Götz in Switzerland, at times when the sun was higher than in the French or Canadian observations, show similar heights. These latter observations also show that there is no large variation in the height of the ozone either with time of year or with the amount of ozone. If anything the height seems to be greater in spring and in cyclonic conditions when the amount of ozone is large.

The temperature of the upper air, deduced from the observations of meteors, indicates that the temperature above 55 kms. is relatively high compared to that below. These observations do not indicate at what height the temperature begins to rise with increasing height.

Again, the observations of sound waves at a great distance from their source indicate that the temperature begins to rise at a height of about 35 kms. and reaches a temperature equal to that at the ground at a height of about 40 to 45 kms., while it continues to rise up to heights of some 60 kms. or more.

The high temperature at these great heights can only be explained by the presence of ozone which absorbs some 6 to 7 per cent of the total incoming solar energy, while it can radiate but little energy. The calculations of Gowan of the temperature at different heights, taking account of the presence of ozone, is in reasonably good agreement with the results from meteors and sound waves, thus confirming the existence of ozone at 40 kms. and more.

There is little, if any, ozone in the lower air as shown by the experiments of Lord Rayleigh and Dr. Götz.

IV. The changes in the amount of ozone in cyclones and anticyclones might be explained by assuming that the great polar and equatorial air currents associated with these pressure systems extend up to heights of 50 kms., or more, and carry with them the amount of ozone which was present at the place of their origin. This simple explanation cannot, however, be true since the following arguments show that these polar and equatorial currents do not extend above about 20 kms.

a. The low temperature of the stratosphere near the equator and its high temperature near the Poles seems to continue up to heights of at least 20 kms. and probably more.
b. The temperature at 20 kms. is practically the same over cyclones as over anticyclones, and does not vary much from the normal temperature of the stratosphere for the latitude.
c. The above results indicate that the polar and equatorial currents associated with cyclones and anticyclones do not extend up to 20 kms., since otherwise the temperature at this height would vary in the same manner as that at 12 to 16 kms.
d. Further, direct observations of balloons at great heights show that the wind velocity, and therefore the pressure gradient, falls off with increasing height in the stratosphere and is very small at 18 to 20 kms. This again indicates that the effect of the cyclone does not extend above 20 kms.

V. The ozone is destroyed rather than formed by solar radiation. This is shown by the following observations:

a. The amount of ozone is small at places in the Tropics.
b. The amount of ozone at the Poles reaches a maximum in the spring at the end of the long winter night, and a minimum in autumn after the long summer day, the amount of ozone falling very rapidly about May when the total solar energy received per day is increasing fast.

The decomposition of ozone by sunlight seems to be slow as there is no appreciable difference between the average amount measured soon after sunrise and that measured shortly before sunset.

VI. The following two important questions can not, unfortunately, be answered at present, and further progress will probably depend on their solution:

a. *How is the atmospheric ozone formed?*

The only action which seems likely is one connected with the aurora. The visible aurora seldom comes lower than 95 kms. so that this itself can not be the immediate cause as ozone formed at this height would sink very slowly. Again, if formed only in high latitudes and destroyed by sunlight one would expect that air which had been circulating for a long time in equatorial regions would have very little ozone, whereas we find that it has a fairly uniform amount, equal to about half that found at the Poles in spring. It is possible that the amount of ozone which would be in equilibrium under the action of all the wave lengths of sunlight is about that found in tropical regions so that sunlight tends to reduce the amount of ozone to this level but not below it.

b. *What causes the connection between the amount of ozone and the conditions at about 10 kms.?*

Since the action of polar and equatorial currents can not affect the amount of ozone (see IV), it is difficult to suggest any action by which the conditions in the upper troposphere or lower stratosphere could affect this amount without reducing the average height of the layer when there is much ozone. Such a reduction of height has been shown not to take place. It is, equally unlikely that changes in the amount of ozone could produce the pressure differences below, since the only appreciable action would seem to be to change the amount of solar energy absorbed, and this change is small. The proportion of the total solar energy absorbed by the ozone layer is about 5.6 per cent when there is little ozone and about 6.7 per cent when there is much ozone. Further the connection between the amount of ozone and the pressure at about 10 kms. is much closer that that between the ozone and the temperature above 10 kms.